

What is claimed is:

1 1. A method for robust single-pass variable bit rate video encoding, the method
2 comprising:
3 determining a buffer size for keeping track of over/underused bits generated
4 during the encoding of a video sequence, the buffer size being a function
5 of at least a target bit rate for the video sequence and a length of the video
6 sequence;
7 initializing the buffer to a default initial fullness; and
8 for each frame of the video sequence, performing the following steps:
9 allocating a number of bits to the frame;
10 determining a quant with which to encode the frame, the quant being a
11 function of at least the buffer's fullness;
12 encoding the frame according to the determined quant; and
13 updating the fullness of the buffer based on any over/underused bits for
14 the frame.

1 2. The method of claim 1 wherein frames in a GOP are encoded, the method further
2 comprising:
3 allocating a segment of the buffer for keeping track of over/underused bits for I
4 frames, a segment for keeping track of over/underused bits for P frames
5 and a segment for keeping track of over/underused bits for B frames;
6 initializing each segment of the buffer to a default initial fullness;

determining a number of I frames per GOP, a number of P frames per GOP and a number of B frames per GOP, based on a nominal GOP pattern;

for each frame of the video sequence, determining the quant with which to encode that frame as a function of at least the fullness of the segment of the buffer for that frame type; and

for each GOP of the video sequence, performing the following steps:

before encoding any frame of that GOP, calculating a GOP bit target for that GOP, the GOP bit target being a function of at least the number of I frames, P frames and B frames per GOP, the target bit rate for the video sequence and any bits carried over from a last encoded GOP;

after encoding each frame of that GOP, calculating over/underused bits by subtracting allocated bits from actual used bits, adding any over/underused bits to an appropriate buffer segment to an extent to which the appropriate buffer segment is not over/underflowed and storing any over/underflow bits in a counter; and

after encoding all frames of that GOP, redistributing over/underused bits between the segments of the buffer as a function of at least a total number of over/underused bits in the buffer and the number of I frames, P frames and B frames per GOP and storing an indication of a number of over/underused bits with respect to the allocated target bits for that GOP to carry over to the next GOP.

1 3. The method of claim 2 further comprising:

2 storing information concerning over/underused of at least some encoded frames

3 by frame type; and

4 using the stored information concerning over/underused bits of frames of a

5 specific frame type in determining quants with which to encode frames of

6 that type.

1 4. The method of claim 3 wherein storing information concerning over/underused of at

2 least some encoded frames by frame type further comprises:

3 storing information concerning over/underused of a specific number of most

4 recently encoded I frames, P frames and B frames.

1 5. The method of claim 1 or 2, wherein:

2 the buffer is a virtual buffer storing information concerning a number of

3 over/underused bits, without storing the over/underused bits themselves.

1 6. The method of claim 2 further comprising:

2 before encoding any frame, initializing to a default initial value at least one

3 parameter from a group of parameters consisting of:

4 a base quant envelope for each frame type;

5 a base quant envelope control for each frame type;

6 ratio information concerning frame types; and

7 a frame complexity parameter for each frame type.

1 7. The method of claim 2 further comprising:

2 for each GOP of the video sequence, before encoding any frame of that GOP,
3 determining whether the fullness of each segment of the buffer is at least
4 at an associated minimal value; and
5 responsive to the fullness of a segment of the buffer not being at least at the
6 associated minimal value, adjusting the fullness of the segment
7 accordingly.

1 8. The method of claim 2 wherein allocating a number of bits to a frame further
2 comprises:

3 allocating bits to the frame according to a modified TM5 reference model, the
4 allocation utilizing at least one an additional parameter from a group of
5 parameters consisting of:
6 at least one frame complexity parameter for a last encoded frame of a frame type;
7 a GOP bit target for the GOP being processed;
8 ratio information concerning frame types within a GOP;
9 the number of I frames per GOP;
10 the number of P frames per GOP; and
11 the number of B frames per GOP.

1 9. The method of claim 1 wherein allocating a number of bits to a frame further
2 comprises:

3 allocating bits to the frame according to a TM5 reference model.

1 10. The method of claim 2 wherein determining a quant with which to encode the frame
2 further comprises:

3 prior to determining the quant, normalizing the fullness of the segment
4 corresponding to the type of frame to encode, based on at least the
5 segment size and the non-normalized segment fullness; and
6 determining the quant as a function of at least a base quant envelope and the
7 normalized segment fullness.

1 11. The method of claim 10 further comprising:

2 adjusting the determined quant based on the frame being a transition frame in the
3 video sequence.

1 12. The method of claim 1 further comprising:

2 after encoding each frame of the video sequence, determining whether the
3 encoding of that frame causes a VBV buffer underflow;
4 responsive to determining that the encoding of that frame causes a VBV buffer
5 underflow, adjusting the quant used to encode the frame; and
6 re-encoding the frame with the adjusted quant so as to eliminate the VBV buffer
7 underflow.

1 13. The method of claim 2 further comprising:

2 after encoding each frame of the video sequence, updating at least one parameter
3 from a group of parameters consisting of:
4 a base quant envelope for the encoded frame type;

ratio information concerning frame types; and
a frame complexity parameter for the encoded frame type.

14. The method of claim 13 further comprising:

updating the base quant envelope for the encoded frame type, as a function of at
least a base quant envelope control for the encoded frame type, an
indicator of the over/underflow bit status of the encoded frame, and the
non-updated base quant envelope for the encoded frame type.

15. The method of claim 10 further comprising:

adding the counter of unallocated over/underflow bits to the buffer segment
corresponding to the type of frame to encode, to an extent that the buffer
segment is not overflowed or underflowed; and
retaining any over/underflow bits that cannot be added to the segment in the
counter.

16. A computer system for robust single-pass variable bit rate video encoding, the
computer system comprising:

means for determining a buffer size for keeping track of over/underused bits
generated during the encoding of a video sequence, the buffer size being a
function of at least a target bit rate for the video sequence and a length of
the video sequence;
means for initializing the buffer to a default initial fullness; and
means for performing the following steps for each frame of the video sequence:
allocating a number of bits to the frame;

10 determining a quant with which to encode the frame, the quant being a
11 function of at least the buffer's fullness;
12 encoding the frame according to the determined quant; and
13 updating the fullness of the buffer based on any over/underused bits for
14 the frame.

1 17. The computer system of claim 16 wherein frames in a GOP are encoded, the
2 computer system further comprising:
3 means for allocating a segment of the buffer for keeping track of over/underused
4 bits for I frames, a segment for keeping track of over/underused bits for P
5 frames and a segment for keeping track of over/underused bits for B
6 frames;
7 means for initializing each segment of the buffer to a default initial fullness;
8 means for determining a number of I frames per GOP, a number of P frames per
9 GOP and a number of B frames per GOP, based on a nominal GOP
10 pattern;
11 means for determining the quant with which to encode that frame as a function of
12 at least the fullness of the segment of the buffer for that frame type for
13 each frame of the video sequence; and
14 means for performing the following steps for each GOP of the video sequence:
15 before encoding any frame of that GOP, calculating a GOP bit target for
16 that GOP, the GOP bit target being a function of at least the
17 number of I frames, P frames and B frames per GOP, the target bit

18 rate for the video sequence and any bits carried over from a last
19 encoded GOP;
20 after encoding each frame of that GOP, calculating over/underused bits by
21 subtracting allocated bits from actual used bits, adding any
22 over/underused bits to an appropriate buffer segment to an extent
23 to which the appropriate buffer segment is not over/underflowed
24 and storing any over/underflow bits in a counter; and
25 after encoding all frames of that GOP, redistributing over/underused bits
26 between the segments of the buffer as a function of at least a total
27 number of over/underused bits in the buffer and the number of I
28 frames, P frames and B frames per GOP and storing an indication
29 of a number of over/underused bits with respect to the allocated
30 target bits for that GOP to carry over to the next GOP.

1 18. The computer system of claim 17 further comprising:

2 means for storing information concerning over/underused of at least some
3 encoded frames by frame type; and
4 means for using the stored information concerning over/underused bits of frames
5 of a specific frame type in determining quants with which to encode
6 frames of that type.

1 19. The computer system of claim 18 wherein the means for storing information
2 concerning over/underused of at least some encoded frames by frame type further comprises:

3 means for storing information concerning over/underused of a specific number of
4 most recently encoded I frames, P frames and B frames.

1 20. The computer system of claim 16 or 17, wherein:

2 the buffer is a virtual buffer storing information concerning a number of
3 over/underused bits, without storing the over/underused bits themselves.

1 21. The computer system of claim 17 wherein the means for determining a quant with
2 which to encode the frame further comprises:

3 means for, prior to determining the quant, normalizing the fullness of the segment
4 corresponding to the type of frame to encode, based on at least the
5 segment size and the non-normalized segment fullness; and
6 means for determining the quant as a function of at least a base quant envelope
7 and the normalized segment fullness.

1 22. The computer system of claim 21 further comprising:

2 means for adding the counter of unallocated over/underflow bits to the buffer
3 segment corresponding to the type of frame to encode, to an extent that the
4 buffer segment is not overflowed or underflowed; and
5 means for retaining any over/underflow bits that cannot be added to the segment
6 in the counter.

1 23. The computer system of claim 16 further comprising:

2 means for, after encoding each frame of the video sequence, determining whether
3 the encoding of that frame causes a VBV buffer underflow;

4 means for, responsive to determining that the encoding of that frame causes a
5 VBV buffer underflow, adjusting the quant used to encode the frame; and
6 means for re-encoding the frame with the adjusted quant so as to eliminate the
7 VBV buffer underflow.

1 24. A computer system for robust single-pass variable bit rate video encoding, the
2 computer system comprising:
3 a portion configured to determine a buffer size for keeping track of
4 over/underused bits generated during the encoding of a video sequence,
5 the buffer size being a function of at least a target bit rate for the video
6 sequence and a length of the video sequence;
7 a portion configured to initialize the buffer to a default initial fullness; and
8 a portion configured to perform the following steps for each frame of the video
9 sequence:
10 allocate a number of bits to the frame;
11 determine a quant with which to encode the frame, the quant being a
12 function of at least the buffer's fullness;
13 encode the frame according to the determined quant; and
14 update the fullness of the buffer based on any over/underused bits for the
15 frame.

1 25. The computer system of claim 24 wherein frames in a GOP are encoded, the
2 computer system further comprising:

3 a portion configured to allocate a segment of the buffer for keeping track of
4 over/underused bits for I frames, a segment for keeping track of
5 over/underused bits for P frames and a segment for keeping track of
6 over/underused bits for B frames;
7 a portion configured to initialize each segment of the buffer to a default initial
8 fullness;
9 a portion configured to determine a number of I frames per GOP, a number of P
10 frames per GOP and a number of B frames per GOP, based on a nominal
11 GOP pattern;
12 a portion configured to determine the quant with which to encode that frame as a
13 function of at least the fullness of the segment of the buffer for that frame
14 type for each frame of the video sequence; and
15 a portion configured to perform the following steps for each GOP of the video
16 sequence:
17 before encoding any frame of that GOP, calculate a GOP bit target for that
18 GOP, the GOP bit target being a function of at least the number of
19 I frames, P frames and B frames per GOP, the target bit rate for the
20 video sequence and any bits carried over from a last encoded GOP;
21 after encoding each frame of that GOP, calculate over/underused bits by
22 subtracting allocated bits from actual used bits, add any
23 over/underused bits to an appropriate buffer segment to an extent
24 to which the appropriate buffer segment is not over/underflowed
25 and store any over/underflow bits in a counter; and

26 after encoding all frames of that GOP, redistribute over/underused bits
27 between the segments of the buffer as a function of at least a total
28 number of over/underused bits in the buffer and the number of I
29 frames, P frames and B frames per GOP and store an indication of
30 a number of over/underused bits with respect to the allocated target
31 bits for that GOP to carry over to the next GOP.

1 26. The computer system of claim 25 further comprising:
2 a portion configured to store information concerning over/underused of at least
3 some encoded frames by frame type; and
4 a portion configured to use the stored information concerning over/underused bits
5 of frames of a specific frame type in determining quants with which to
6 encode frames of that type.

1 27. The computer system of claim 26 wherein the portion configured to store
2 information concerning over/underused of at least some encoded frames by frame type further
3 comprises:
4 a portion configured to store information concerning over/underused of a specific
5 number of most recently encoded I frames, P frames and B frames.

1 28. The computer system of claim 24 or 25 wherein:
2 the buffer is a virtual buffer storing information concerning a number of
3 over/underused bits, without storing the over/underused bits themselves.

1 29. The computer system of claim 25 wherein the portion configured to determine a
2 quant with which to encode the frame further comprises:

3 a portion configured to, prior to determining the quant, normalize the fullness of
4 the segment corresponding to the type of frame to encode, based on at
5 least the segment size and the non-normalized segment fullness; and
6 a portion configured to determine the quant as a function of at least a base quant
7 envelope and the normalized segment fullness.

1 30. The computer system of claim 29 further comprising:

2 a portion configured to add the counter of unallocated over/underflow bits to the
3 buffer segment corresponding to the type of frame to encode, to an extent
4 that the buffer segment is not overflowed or underflowed; and
5 a portion configured to retain any over/underflow bits that cannot be added to the
6 segment in the counter.

1 31. The computer system of claim 24 further comprising:

2 a portion configured to, after encoding each frame of the video sequence,
3 determine whether the encoding of that frame causes a VBV buffer
4 underflow;
5 a portion configured to, responsive to determining that the encoding of that frame
6 causes a VBV buffer underflow, adjust the quant used to encode the
7 frame; and
8 a portion configured to re-encode the frame with the adjusted quant so as to
9 eliminate the VBV buffer underflow.

1 32. A computer readable medium containing a computer program product for robust
2 single-pass variable bit rate video encoding, the computer program product comprising:

3 program code for determining a buffer size for keeping track of over/underused
4 bits generated during the encoding of a video sequence, the buffer size
5 being a function of at least a target bit rate for the video sequence and a
6 length of the video sequence;

7 program code for initializing the buffer to a default initial fullness; and

8 program code for performing the following steps for each frame of the video
9 sequence:

10 allocating a number of bits to the frame;

11 determining a quant with which to encode the frame, the quant being a
12 function of at least the buffer's fullness;

13 encoding the frame according to the determined quant; and

14 updating the fullness of the buffer based on any over/underused bits for
15 the frame.

1 33. The computer program product of claim 32 wherein frames in a GOP are encoded,
2 the computer program product further comprising:

3 program code for allocating a segment of the buffer for keeping track of

4 over/underused bits for I frames, a segment for keeping track of

5 over/underused bits for P frames and a segment for keeping track of

6 over/underused bits for B frames;

7 program code for initializing each segment of the buffer to a default initial
8 fullness;
9 program code for determining a number of I frames per GOP, a number of P
10 frames per GOP and a number of B frames per GOP, based on a nominal
11 GOP pattern;
12 program code for determining the quant with which to encode that frame as a
13 function of at least the fullness of the segment of the buffer for that frame
14 type for each frame of the video sequence; and
15 program code for performing the following steps for each GOP of the video
16 sequence:
17 before encoding any frame of that GOP, calculating a GOP bit target for
18 that GOP, the GOP bit target being a function of at least the
19 number of I frames, P frames and B frames per GOP, the target bit
20 rate for the video sequence and any bits carried over from a last
21 encoded GOP;
22 after encoding each frame of that GOP, calculating over/underused bits by
23 subtracting allocated bits from actual used bits, adding any
24 over/underused bits to an appropriate buffer segment to an extent
25 to which the appropriate buffer segment is not over/underflowed
26 and storing any over/underflow bits in a counter; and
27 after encoding all frames of that GOP, redistributing over/underused bits
28 between the segments of the buffer as a function of at least a total
29 number of over/underused bits in the buffer and the number of I

30 frames, P frames and B frames per GOP and storing an indication
31 of a number of over/underused bits with respect to the allocated
32 target bits for that GOP to carry over to the next GOP.

1 34. The computer program product of claim 32 further comprising:
2 program code for storing information concerning over/underused of at least some
3 encoded frames by frame type; and
4 program code for using the stored information concerning over/underused bits of
5 frames of a specific frame type in determining quants with which to
6 encode frames of that type.

1 35. The computer program product of claim 34 wherein the program code for storing
2 information concerning over/underused of at least some encoded frames by frame type further
3 comprises:
4 program code for storing information concerning over/underused of a specific
5 number of most recently encoded I frames, P frames and B frames.

1 36. The computer program product of claim 32 or 33 wherein:
2 the buffer is a virtual buffer storing information concerning a number of
3 over/underused bits, without storing the over/underused bits themselves.

1 37. The computer program product of claim 33 wherein the program code for
2 determining a quant with which to encode the frame further comprises:

3 program code for, prior to determining the quant, normalizing the fullness of the
4 segment corresponding to the type of frame to encode, based on at least
5 the segment size and the non-normalized segment fullness; and
6 program code for determining the quant as a function of at least a base quant
7 envelope and the normalized segment fullness.

1 38. The computer program product of claim 37 further comprising:

2 program code for adding the counter of unallocated over/underflow bits to the
3 buffer segment corresponding to the type of frame to encode, to an extent
4 that the buffer segment is not overflowed or underflowed; and
5 program code for retaining any over/underflow bits that cannot be added to the
6 segment in the counter.

1 39. The computer program product of claim 32 further comprising:

2 program code for, after encoding each frame of the video sequence, determining
3 whether the encoding of that frame causes a VBV buffer underflow;
4 program code for, responsive to determining that the encoding of that frame
5 causes a VBV buffer underflow, adjusting the quant used to encode the
6 frame; and
7 program code for re-encoding the frame with the adjusted quant so as to eliminate
8 the VBV buffer underflow.